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637.0003USU

JC866 U.S. PTO 07/27/00

JC586 U.S. PTO 09/627559 07/27/00

UNITED STATES PATENT APPLICATION TRANSMITTAL FORM

BOX PATENT APPLICATION
ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

Docket No.: 637.0003USU

Sir:

Transmitted herewith for filing is the patent application of

Inventor(s): Jörg Schultz et al.

For: **ILLUMINATION SYSTEM WITH A PLURALITY OF LIGHT SOURCES**

Enclosed are:

XXX Specification (25 pps.) consisting of: Description (18 pps); Claims (6 pps); Abstract (1pp);

XXX 9 sheets of drawing;

____ Declaration and Power of Attorney;

____ An assignment of the invention to: __________, including $40.00 recordation fee and Assignment Recordation Form Cover Sheet;

____ Verified Statement (Declaration Claiming Small Entity Status - Small Business Concern;

____ Information Disclosure Statement (with copies of patent);

____ Form - PTO-1449;

XXX Priority of application Serial No. 199 35 404.9 filed on July 30, 1999, in Germany is claimed under 35 U.S.C. §119;

XXX Priority application Serial No. 199 35 404.9 filed on July 30, 1999, in Germany is enclosed herewith;

XXX Preliminary Amendment.

637.0003USU

The Filing Fee is calculated below.

CLAIMS AS FILED				
(1) For	(2) Number Filed	(3) Number Extra	(4) Rate	(5) Basic Fee $690.00
Total Claims	22 - 20 =	2	x $18.00	$36.00
Independent Claims	1 - 3 =	0	x $78.00	$0.00
Multiple Dependent Claim Fee			x $260.00 =	$0.00
TOTAL FILING FEE				**$726.00**
1/2 FILING FEE FOR SMALL ENTITY				$

XXX A check in the amount of $ **726.00** to cover the filing fee is enclosed.

XXX The Commissioner is hereby authorized to charge any additional fees under 37 C.F.R. §§1.16 and 1.17 which may be required with this communication or during the entire pendency of the application, or credit any overpayment, to **Deposit Account No. 01-0467.** A duplicate copy of this Form is enclosed.

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John Yankovich
(Typed name of person mailing paper)

(Signature of person mailing paper)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants:	Schultz et al.
Serial No:	Not Yet Assigned
For:	ILLUMINATION SYSTEM WITH A PLURALITY OF LIGHT SOURCES
Filed:	Concurrently Herewith
Examiner:	Not Yet Assigned
Art Unit:	Not Yet Assigned

Docket No.: 637.0003USU

PRELIMINARY AMENDMENT

Box: Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Preliminary to examination, please amend the above-noted patent application as follows:

IN THE DRAWINGS

Please replace drawing sheets 1, 2 and 5 with amended sheets 1, 2 and 5, included herewith.

IN THE SPECIFICATION

Please amend the Specification as follows:

Page 8, line 18, delete "Figure 4 shows" and replace it with --Figures 4A - 4B show--.

Page 11, line 25, delete "Figure 5" and replace it with --Figures 4A through 4D with coupling of 3, 4, 5 and 6 sources--.

Page 16, line 14, after "108" insert --, as shown in Figure 10,--.

IN THE CLAIMS

Please amend the claims as follows:

Cancel claims 1 through 37.

Add new claims 38 through 59 as follows:

--38. Illumination system for wavelengths $\leq$ 193 nm, comprising:

a plurality of primary light sources;

an optical unit combining said plurality of primary light sources; and

a first plurality of raster elements transforming said plurality of primary light sources into a plurality of secondary light sources,

wherein said first plurality of raster elements is imaged into a plane whereby a plurality of images is formed.

39. The illumination system of claim 38, wherein each of said first plurality of raster elements has a concave surface.

40. The illumination system of claim 38, comprising a collector unit.

41. The illumination system of claim 40, wherein each of said first plurality of raster elements has a planar surface, and wherein said collector unit and said first plurality of raster elements transform said plurality of primary light sources into said plurality of secondary light sources.

42. The illumination system of claim 38, wherein each of said first plurality of raster elements is arranged and oriented to superimpose said plurality of images in said plane forming an illuminated field.

43. The illumination system of claim 42, wherein said optical unit has a shape of a pyramid with a plurality of sides, wherein each of said plurality of sides corresponds to one of said plurality of primary light sources, and wherein said first plurality of raster elements is arranged on said plurality of sides.

44. The illumination system of claim 43, wherein each of said plurality of sides is oriented to superimpose said plurality of images in said plane.

45. The illumination system of claim 38, further comprising a second plurality of raster elements.

46. The illumination system of claim 45, wherein said second plurality of raster elements is located at said plurality of secondary light sources, wherein each of said plurality of secondary light sources is located on one of said second plurality of raster elements, and wherein each of said first plurality of raster elements and each of said second plurality of raster elements is arranged and oriented to superimpose said plurality of images in said plane forming an illuminated field.

47. The illumination system of claim 46, wherein each of said second plurality of raster elements has a concave surface.

48. The illumination system of claim 47, wherein said optical unit has a shape of a pyramid with a plurality of sides, wherein each of said plurality of sides corresponds to one of said plurality of primary light sources, and wherein said second plurality of raster elements is arranged on said plurality of sides.

49. The illumination system of claim 48, wherein each of said plurality of sides is oriented to superimpose said plurality of images in said plane forming an illuminated field.

50. The illumination system of claim 46, wherein said optical unit comprises a plurality of pyramids, wherein each of said plurality of pyramids has a plurality of sides, wherein each of said plurality of sides corresponds to one of said plurality of primary light sources, and wherein each of said second plurality of raster elements is arranged on one of said plurality of sides of said plurality of pyramids.

51. The illumination system of claim 50, wherein each of said plurality of sides of said plurality of pyramids is oriented to superimpose said plurality of images in said plane forming an illuminated field.

52. The illumination system of claim 51, wherein each of said second plurality of raster elements has a concave surface.

53. The illumination system of claim 51, wherein each of said second plurality of raster elements has a planar surface.

54. The illumination system of claim 46, wherein said optical unit comprises said second plurality of raster elements, and wherein each of said second plurality of raster elements is arranged and oriented to superimpose said plurality of images in said plane forming an illuminated field.

55. The illumination system of claim 54, wherein each of said second plurality of raster elements has a concave surface.

56. The illumination system of claim 54, wherein each of said second plurality of raster elements has a planar surface.

57. The illumination system of claim 38, further comprising an optical element and an exit pupil, wherein said optical element is situated in an optical light path between said plurality of secondary light sources and said plane, to image said plurality of secondary light sources into said exit pupil.

58. An EUV-projection exposure system comprising:
the illumination system of claim 38;
a mask located in said plane;
a projection objective lens; and
a light-sensitive object on a carrier system wherein an image of said mask is formed on said light-sensitive object.

59. A method for production of microelectronic components, comprising the step of using said EUV-projection exposure system of claim 58.--

REMARKS

This application now contains claims 38 through 59.

Drawing sheet 1, Fig. 1 was amended to properly show reference numeral 6. Drawing sheet 2, Fig. 3 was amended to properly show reference numerals 30.1 and 30.2. Drawing sheet 5, Fig. 7 was amended to properly show reference numeral 110.

The specification was amended to correct several improper references to the drawings.

Applicant also added Figs. 12 and 13, and added a description thereof in the specification.

Respectfully submitted,

July 28, 2000
Date

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John Yankovich
(Typed name)

(Signature of person mailing paper)

Fig.1

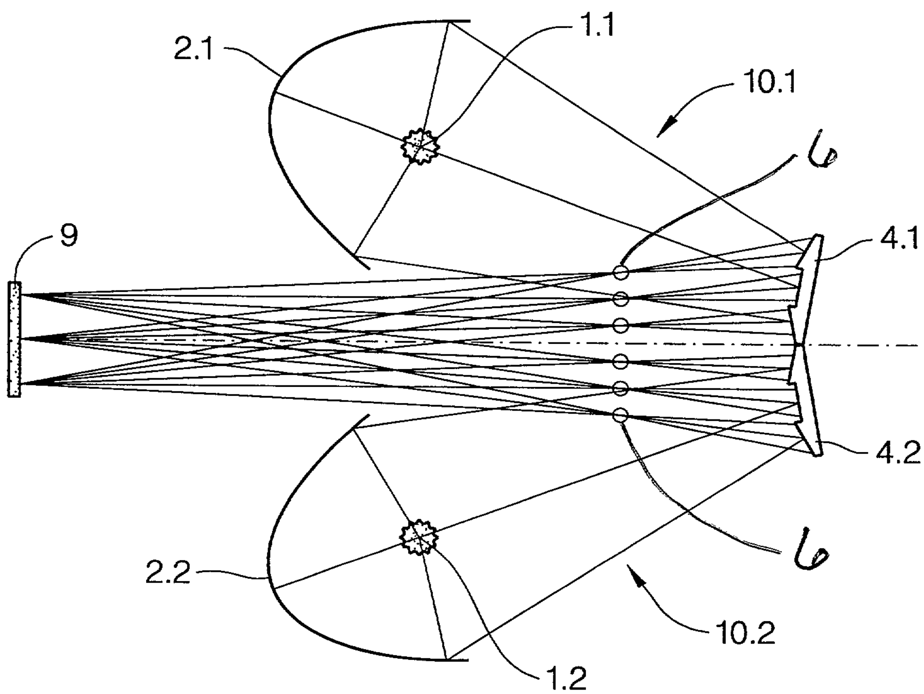


Fig.2

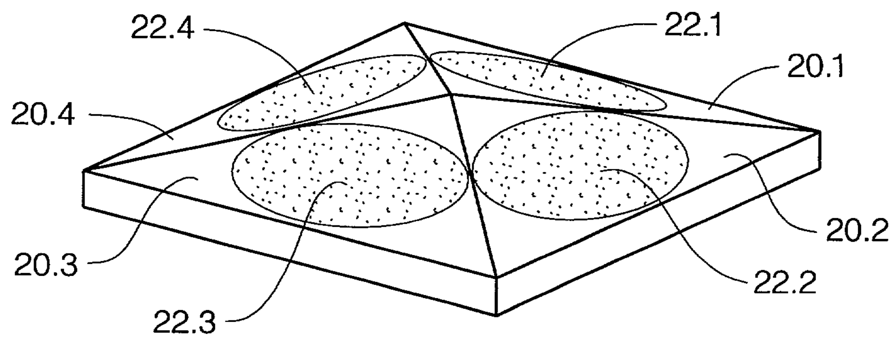


Fig.3

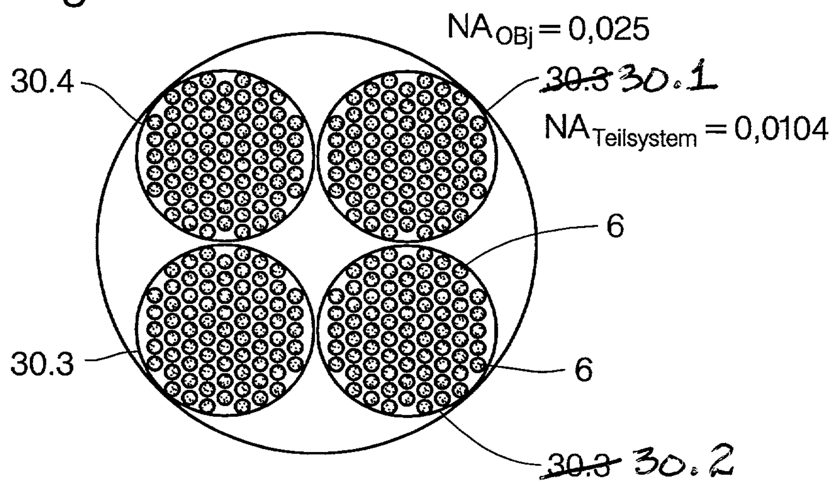


Fig.4A

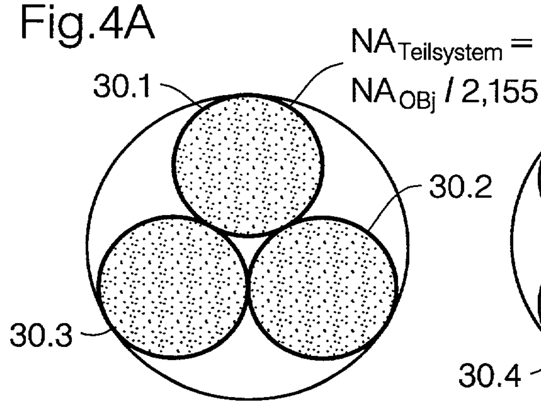


Fig.4B

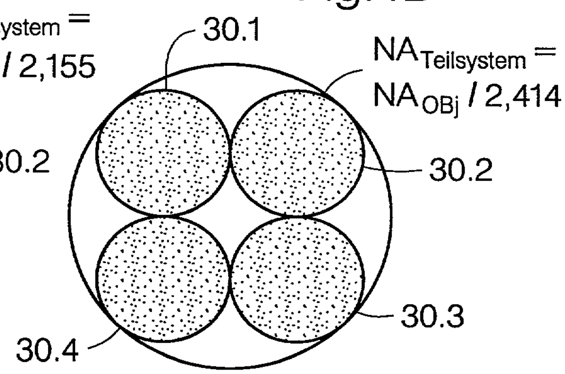


Fig.4C

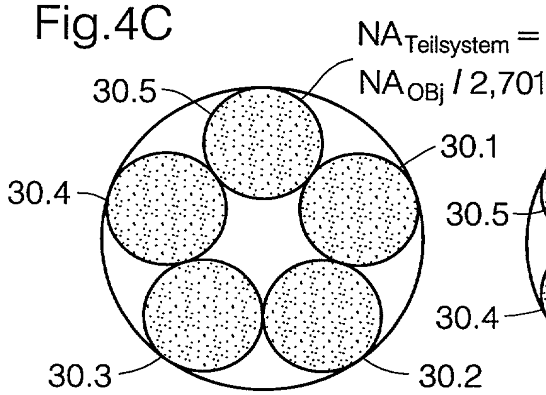


Fig.4D

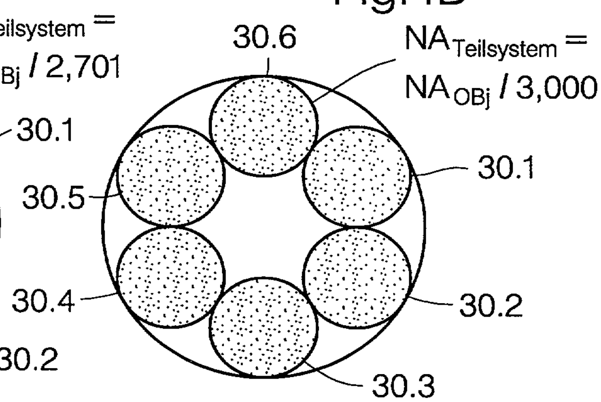


Fig.7

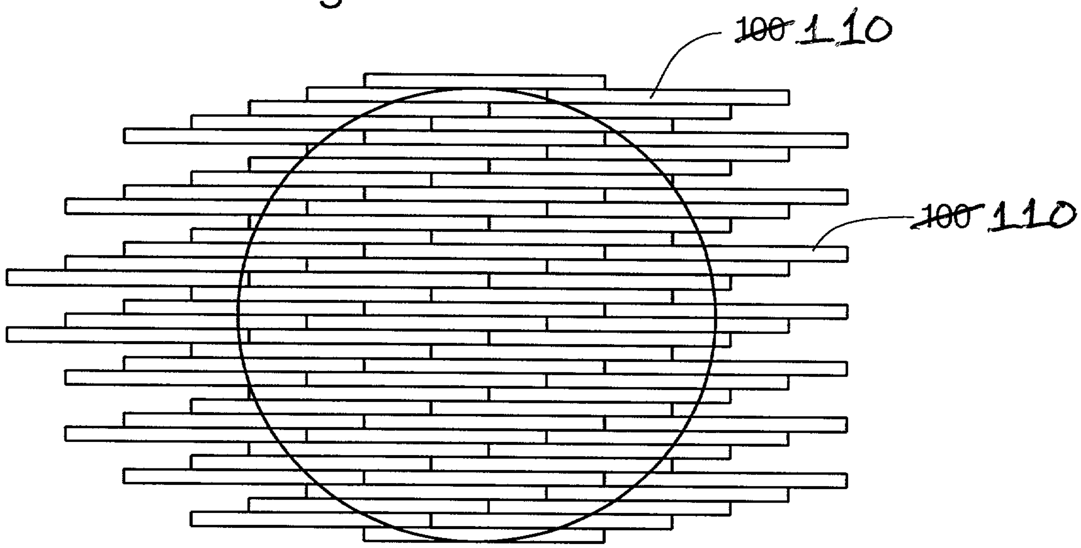
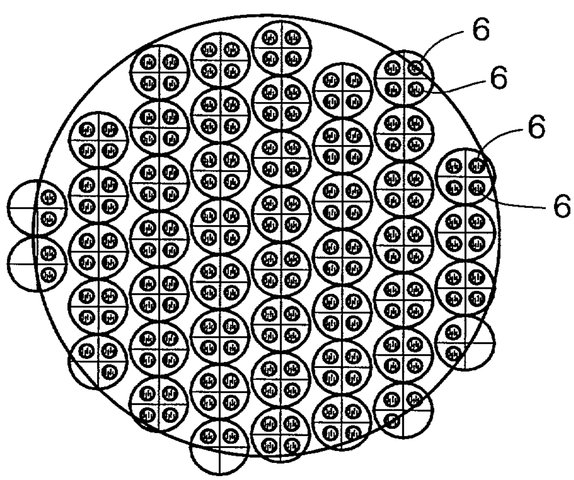


Fig.8



ILLUMINATION SYSTEM WITH A PLURALITY OF LIGHT SOURCES

The invention concerns an illumination system for wavelengths ≤ 193 nm, i.e., VUV and EUV-lithography with a plurality of light sources, for example, as well as a mirror or lens device for producing secondary light sources, comprising several mirrors or lenses, divided into raster elements.

In order to allow even further reduction in the structural width of electronic components, especially to the submicron range, it is necessary to reduce the wavelength of the light used in microlithography.

For wavelengths smaller than 193 nm, lithography with weak x-rays or so-called EUV-lithography is discussed.

A suitable illumination system for EUV-lithography should homogeneously or uniformly illuminate, with as few reflections as possible, a pregiven field for EUV-lithography, especially the annular field of an objective lens, under lithography requirements. Furthermore the pupil of the objective lens should be illuminated up to a particular degree of filling σ, independently of the field, and the exit pupil of the illumination system should be situated in the entrance pupil of the objective lens.

Regarding the basic layout of EUV-illumination systems, we refer to the applicant's pending applications EP 99 106348.8, submitted on March 2,1999, entitled "Illumination system, especially for EUV-lithography", US Serial No. 09/305,017, submitted on May 4, 1999 entitled "Illumination system particularly for EUV-lithography", and PCT/EP 99/02999, submitted on May 4, 1999, entitled "Illumination system, especially for EUV-lithography", whose disclosure contents are incorporated in their entirety in the present application.

The following are discussed herein as light sources for EUV-illumination systems:

laser plasma sources
pinch plasma sources
synchrotron radiation sources

In the case of laser plasma sources, an intensive laser beam is focused onto a target (solid, gas jet, droplet). The target is heated so strongly by the excitation that a plasma is formed. This emits EUV-radiation.

Typical laser plasma sources have a spherical beam, i.e., a radiation angle of 4 π, as well as a diameter of 50 μm to 200 μm.

In pinch plasma sources, the plasma is produced by means of electrical excitation.

Pinch plasma sources can be described as volume radiators (D = 1.00 mm), which emit in 4 π, whereby the beam characteristic is dictated by the source geometry.

In the case of synchrotron radiation sources, one can distinguish three types of sources at present:

- bending magnets
- wigglers
- undulators

In bending magnet sources, the electrons are deflected by a bending magnet and emit photon radiation.

Wiggler sources comprise a so-called wiggler for deflection of the electron or an electron beam, and this wiggler comprises a multiple number of alternating polarized pairs of magnets arranged in rows. If an electron passes through a wiggler, it is subjected to a periodic, vertical magnetic field and the electron oscillates in the horizontal plane. Wigglers are also characterized by the fact that no coherency effects occur. The synchrotron radiation produced by a wiggler is similar to a bending magnet and radiates in a horizontal solid angle. In contrast to the bending magnet, it has a flux that is intensified by the number of poles of the wiggler.

There is no clear dividing line between wiggler sources and undulator sources.

In case of undulator sources, the electrons in the undulator are subjected to a magnetic field of shorter period and smaller magnetic field of the deflection poles than in the case of a wiggler, so that interference effects occur in the synchrotron radiation. The synchrotron radiation has a discontinuous spectrum based on the interference effects and emits both horizontally as well as vertically in a small solid-angle element; i.e., the radiation is highly directional.

It is critical for an EUV-illumination system to provide a sufficiently high Lagrange optical invariant or *etendu*. The Lagrange optical invariant of a system is defined as the product of the illuminated surface times the square of the aperture.

If the aperture in the plane of the wafer is in the range $NA_{wafer} = 0.1\text{-}0.25$, then in the case of 4:1 systems an aperture in the reticle plane of $NA_{reticle} = 0.025\text{-}0.0625$ is needed. If the illumination system is supposed to illuminate this aperture homogeneously and independent from the field up to a filling degree of $\sigma = 0.6$,

for example, the EUV-source must have the following 2-dim Lagrange optical invariant or *etendu*: (LC).

$LC_{ill.} = \sigma^2 \, LC_{Obj} = 0.149 \text{ mm}_2 - 0.928 \text{ mm}^2$

The Lagrange optical invariant LC, is generally defined as follows for the lithography system described herein:

$LC_{ill.} = \sigma^2 x \cdot y \cdot NA^2 = \sigma^2 \, A \cdot NA^2$, wherein A is the illuminated area. The area comprises 110 mm x 6 mm, for example, in the reticle plane.

The Etendu of a laser plasma source can be roughly calculated as the product of the illuminated surface of an imaginary unit sphere around the source and the square of the aperture angle at which each field point of the imaginary unit source sees the spherical source.

$LC \;\; = A \cdot NA^2$

$A^{LPQ} = 2\pi[\cos(\theta_1)\text{-}\cos(\theta_2)]$

$NA \;\; \approx r_{source}/1 \text{ mm} = 0.100$

where θ_1 is the minimum beam angle with respect to the optical axis and θ_2 is the maximum beam angle with respect to the optical axis

$LC_{LPQ} = 2\pi[\cos(\theta_1)\text{-}\cos(\theta_2)] \cdot r^2_{LPQ}$

With the typical source parameters:

1. r_{LPQ} = 0.1 mm, $\theta_1 = 0°$, $\theta_2 = 90°$ yields: LC_{LPQ} = 0.063 mm^2. This corresponds to 27% of the required value of the Lagrange optical invariant LC_{ill} of, for example, 0.236 mm^2.

2. r_{LPQ} = 0.025 mm, $\theta_1 = 0°$, $\theta_2 = 90°$ yields: LC_{LPQ} = 0.0039 mm^2. This corresponds to 1.7% of the required value of the Lagrange optical invariant of, for example, LC_{ill} = 0.236 mm^2.

The Lagrange optical invariant LC_{Pinch} of a pinch plasma source with a diameter of 1 mm, Ω = 0.3 sr, for example, is:

$$LC_{Pinch} = A \cdot NA^2 = \pi \cdot 1 \text{ mm}^2 / 4 \cdot 0.3053^2 = 0.073 \text{ mm}^2.$$

Thus, the pinch plasma source provides 31% of the required value of the Lagrange optical invariant of, for example, LC_{ill} = 0.236 mm^2.

The Lagrange optical invariant or *Etendu* for the undulator source can be estimated by a simplified model assuming a homogeneous two-dimensional radiator with diameter

$\varnothing$ = 1.0 mm and aperture NA_{Und} = 0.001 with

$$LC_{Und} = A \cdot NA^2$$

$$A_{Und} = \pi \cdot (\varnothing /2)^2$$

$$= 0.785 \text{ mm}^2$$

$$NA_{Und} = 0.001$$

as

$$LC_{Und} = A \cdot NA^2 = 0.00000079 \text{ mm}^2 = 7.9\text{e-}07 \text{ mm}^2.$$

As can be seen from this rough calculation the Etendu or Lagrange optical invariant of the undulator source is much too small in comparison to the required value of the Lagrange optical invariant.

To increase the Lagrange optical invariant, an illumination system comprising a synchrotron radiation source known from US 5,512,759, comprises a condenser system with a plurality of collecting mirrors, which collect the radiation emitted by the synchrotron radiation source and form it to an annular light beam that corresponds to the annular field being illuminated. By this, the annular field is illuminated very uniformly. The synchrotron radiation source has a beam divergence > 100 mrad in the plane of radiation.

US 5,439,781 shows an illumination system with a synchrotron radiation source, in which the Lagrange optical invariant, is adjusted by means of a scattering plate in the entrance pupil of the objective lens, wherein the scattering plate can comprise a plurality of pyramidal structures. Also, in US 5,439,781, the synchrotron radiation source has a beam divergence > 100 mrad. The synchrotron radiation according to US 5,439,781 is also focused, for example, by means of a collector mirror.

The disclosure contents of both of the above-mentioned documents

US 5,512,759
US 5,439,781

are incorporated into the disclosure contents of the present application by reference.

The object of the invention is to supply an illumination system of easy construction having the required Etendu in the object - or reticle - plane.

The object of the invention is solved in that several light sources are coupled in order to illuminate the exit pupil of the illumination system up to a predetermined degree of filling.

The coupling of several light sources also results in an increase of intensity. A coupling of several light sources is possible as long as the total Lagrange optical invariant of all coupled sources is less than the Lagrange optical invariant of the illumination system LC_{ill}.

There are three basic possibilities for coupling:

1. Addition method: Identical or similar illumination systems are distributed about an axis of the system. The exit pupil of the illumination system is illuminated by the circular pupils of the system parts, which must not overlap. The partial pupils are located on the side face of a pyramid-shaped input mirror, which superimposes the light bundles on the object or reticle.

2. Mixing method: In this case, each system part illuminates the entire exit pupil of the illumination system, but with regions free of light between the secondary light sources. The individual grids of the secondary light sources are staggered by superimposing, so as to uniformly fill the pupil. The coupling mirror consists of a raster element plate, whose raster elements or facets have the shape of pyramids. Each side face of an individual raster element pyramid is illuminated by a secondary light source.

3. Segment method: Similar to the addition method. Unlike the addition method, a segment of any desired shape is illuminated by appropriate beam deflection, instead of a circular segment of the exit pupil.

Preferred embodiments of the invention making use of at least one of the above-mentioned methods are the subject of the subsidiary claims.

The invention shall now be described by means of the drawings.

Here:

Figure 1 shows a first embodiment of the invention, in which the light of several light sources is superimposed according to the addition method.

Figure 2 shows the arrangement of the raster element field plates on an equilateral pyramid.

Figure 3 shows the illumination of the exit pupil of a system according to Figure 1.

Figure 4 shows illumination of the exit pupil with coupling of 3, 4, 5 and 6 sources.

Figure 5 shows a second embodiment of the invention, in which the light of several light sources is coupled by the addition method in the diaphragm plane.

Figure 6 shows a third embodiment of the invention, in which the light of several light sources is coupled by the mixing method in the diaphragm plane.

Figure 7 shows arrangement of the field raster elements on the field raster element plates of a system according to Figure 6.

Figure 8 shows arrangement of the secondary light sources in the diaphragm plane of a system according to Figure 6.

Figure 9 shows segment of the pupil raster element plate of a system according to Figure 6 with a plurality of pyramids, on whose flanks the pupil raster elements are located.

Figure 10 shows a fourth embodiment of the invention, in which light from several light sources is coupled in the diaphragm plane by means of imaging raster elements according to the mixing method.

Figure 11 shows illumination of a segment of the pupil raster element plate in a system that operates according to the segment method.

Figure 12 shows the illumination system of the second embodiment wherein a field lens is situated in a light path between the plurality of secondary light sources and the reticle plane and some rays are drawn from the two light sources to the exit pupil.

Figure 13 shows a projection exposure system with the illumination system of Fig. 12.

Figure 1 shows the layout of a system in which the light sources are coupled together according to the addition method. The light sources 1.1, 1.2 in the present case have a small source diameter, in this case laser plasma sources are further investigated.

Regarding the basic layout of EUV-illumination systems, we refer to the applicant's pending applications EP 99 1 06348.8, submitted on March 2, 1999,

entitled "Illumination system, especially for EUV-lithography", US Serial No. 09/305,017, submitted on May 4, 1999, entitled "Illumination system particularly for EUV-lithography", and PCT/EP 99/02999, submitted on May 4, 1999, entitled "Illumination system, especially for EUV-lithography", whose disclosure contents are incorporated in their entirety in the present application.

Each system part 10.1, 10.2 is essentially identical in construction and comprises a light source 1.1, 1.2, a collector mirror 2.1, 2.2, and a field raster element plate 4.1, 4.2.

The light of each source is collected by means of the collector mirror assigned to a particular source and transformed into a parallel or convergent light bundle. The field raster elements of the particular field raster element plate 4.1, 4.2 decompose the light bundle and create secondary light sources 6 in the diaphragm plane of the illumination system. These secondary light sources are imaged by the field lens (not shown) or field mirror in the exit pupil of the illumination system, which is the entrance pupil of the objective lens (not shown). The field raster elements of the field raster element plate are arranged on the plate and oriented so that the images of the field raster elements are superimposed in the reticle plane 9.

The systems are brought together where the field raster element plates are located. The field raster element plates are located on a pyramid, the number of the sides of the pyramid corresponds to the number of coupled partial systems. The angle of inclination of the pyramid sides is chosen such that the illuminated fields of the partial systems in the reticle plane 9 are superimposed.

The partial systems parts 10.1, 10.2 are arranged such that their partial pupils fill the diaphragm plane of the illumination system optimally.

In the embodiment shown in the drawings, the partial systems are oriented such that they possess a common system axis. The angular spacing of the partial system is then 360°/number of systems.

For four partial systems, Figure 2 shows the illumination of the pyramid, on each of the four lateral surfaces 20.1, 20.2. 20.3, 20.4 of the pyramid one field raster element plate of a partial system in the area of the illuminated surface 22.1, 22.2, 22.3, 22.4 is arranged.

The field raster elements are arranged and oriented such that the images of the field raster elements overlap in the reticle plane 9. The angle of inclination of the pyramid surfaces 20.1, 20.2. 20.3, 20.4 is chosen such that the illuminated fields of the partial system superimpose in the reticle plane.

The illumination in the diaphragm plane is provided by four circular partial pupils 30.1, 30.2. 30.3, 30.4, as shown in Figure 3, which in turn are divided into individual secondary light sources 6, corresponding to the number of illuminated field raster elements of the field raster element plates.

In Figure 3, the aperture of the total system is $NA_{Obj} = 0.025$ and the aperture of the system parts is $NA_{Teilsystem} = 0.0104$.

Depending on the number of coupled partial systems, one can imagine the arrangement and symmetries of the partial pupils 30.1, 30.2. 30.3, 30.4, 30.5, 30.6 as shown in Figure 5.

The maximum diaphragm diameters of the partial systems are derived from the total aperture NA_{Obj} of the objective lens in the diaphragm plane and the number of partial systems or subsystems.

$$NA_{Teilsystem} = \frac{NA_{Obj}}{1 + \frac{1}{\sin\left(\frac{\pi}{Anzahl}\right)}}$$

Whereby:

Teilsystem = partial system; Anzahl = number of partial systems

When the pupil of each subsystem is filled, the pupil can be illuminated to η% of the maximum.

$$\eta = Anzahl \cdot \frac{1}{\left(1 + \frac{1}{\sin\left(\frac{\pi}{Anzahl}\right)}\right)^2}$$

Whereby:

Anzahl = number of partial systems

The following table gives $NA_{system\ part}$ and the filling factor η for $NA_{Obj} = 0.025$:

Number of system parts	$NA_{system\ parts}$	Filling factor η_{max}
2	0.0125	0.500
3	0.0116	0.646
4	0.0104	0.686
5	0.0093	0.685
6	0.0083	0.667
7	0.0076	0.641

8	0.0069	0.613
9	0.0064	0.585
10	0.0059	0.557

Hence, the maximum attainable filling factor with the addition method using four subsystems and $NA_{Obj} = 0.025$ is achieved with $\eta_{max} \approx 0.69$. As a boundary condition, the overall Etendu of the coupled sources may not exceed the system Etendu $LC_{ill} = \eta_{max} \cdot LC_{Obj}$; thus, we must always have:

$$\sum_{\text{all sources}} LC_i \leq LC_{ill}$$

Figure 5 shows a second form of embodiment of the invention, in which the light sources 50.1, 50.2 are pinch plasma sources, for example. The source diameter of the pinch plasma sources is not negligible.

A partial illumination system with pinch plasma source comprises the light source 50.1, 50.2, a collector mirror 52.1, 52.2, which collects the light and illuminates the field raster element plate 54.1, 54.2. The field raster elements of the plate produce secondary light sources. At the location of the secondary light sources, the pupil raster elements are arranged on a pupil raster element plate. The field raster elements of the field raster element plate are used to shape the field and the pupil raster element of the pupil raster element plate correctly image the field raster element in the reticle plane. Preferably, each field raster element is assigned to a pupil raster element. The light is guided by reflection from the field raster elements of the field raster element plates to the pupil raster

element of the pupil raster element plate 56.1, 56.2 and from there to the reticle, or object 58.

The systems are brought together at the location of the pupil raster element plates. The pupil raster element plates are located on a pyramid. The number of sides of the pyramid corresponds to the number of coupled subsystems. The angle of inclination of the pyramid sides is chosen such that the illuminated fields of the partial systems or subsystems are brought together in the reticle plane.

If the subsystems have a common system axis, then the angular spacing of the system parts is 360°/number of systems and the pupil raster element plates of the subsystem are preferably arranged on the lateral surfaces of a pyramid, as shown in Figure 2.

The advantage of the addition method of coupling is that identical or similar illumination systems can be coupled together. The raster element plates of the subsystems are separate and can thus be fabricated separately.

In the addition method, it should be noted that intensity differences of the individual sources are directly passed on to the illumination of the pupils, and thus the intensity of the partial pupils is dictated by the source power.

The intensity distribution in the diaphragm plane becomes independent of the intensities of the individual sources if one mixes the secondary light sources in the pupil plane. This technique is also hereafter designated as the mixing method.

Whereas in the addition method the beam bundles of each source only penetrate after passing through the diaphragm plane, in the mixing method the

beam bundles penetrate in front of the diaphragm plane and are mixed in the diaphragm plane. The maximum aperture for each subsystem is adapted to the desired angle of filling of the objective aperture. As in the addition method, systems of identical construction can be coupled together for the individual sources. They are uniformly arranged about a common system axis. The systems are coupled together in the plane of the secondary light sources.

Figure 6 shows an illumination system based on the mixing method for coupling of several light sources.

The light sources once again are laser plasma sources. The same components as in Figure 5 are designated with the same reference numbers. In contrast to Figure 5, for example, there is a single pupil raster element plate 100, which includes a plurality of pyramids. The pupil raster element plate 100 is arranged at the location of the secondary light sources, which are produced by the field raster elements. A secondary light source is located on each flank, or lateral side, of the plurality of pyramids.

The schematic representation of Figure 7 shows a typical arrangement of the field raster elements 110 on the field raster element plate. Each field raster element plate produces a grid of secondary light sources in the diaphragm plane. The distribution of the secondary light sources in the diaphragm plane corresponds to the arrangement of the field raster elements.

By shifting the subsystems, as depicted in Figure 8, the grids of secondary light sources can be brought to be located next to each other, corresponding to the number of subsystems.

If four sources are coupled together, the arrangement of secondary light sources 6 shown in the schematic representation of Figure 8 is obtained. For the correct

superimposing of the four subsystems, each set of secondary light sources is located on a mirrored pyramid. The flanks of the pyramid are inclined such that the images of the field raster elements are superimposed in the reticle plane. The schematic representation of Figure 9 shows a segment of the pupil raster element plate. One clearly recognizes the individual pupil raster elements 104 that are formed by the flanks of an equilateral pyramid 106.

If the Etendu (LC) of the individual sources is small, the pupil raster elements can be designed as plane mirrors, i.e., the flanks of the equilateral pyramids 106 are planar.

When the source diameter is not negligible, such as with pinch plasma sources, the pupil raster elements 104 must image the field raster elements in the object plane, for example, the reticle plane. In this case, a concave mirror surface 108 must be worked into the pyramid flanks.

The schematic representation of Figure 10 shows a system in which several pinch plasma sources are coupled with a pupil raster element plate comprising pupil raster elements with concave surfaces. The same components as in Figure 6 are given the same reference numbers.

The examples shown in Figures 5 through 10 are designed for four coupled sources. However, the same method can be used for three, five, six or more sources. The grids should then be shifted such that the secondary light sources are located on the side faces of pyramids. The degree of filling of the pupil is limited similar to the addition method.

The advantages of the mixing method are that the individual sources are mixed in the pupil plane. Fluctuations in source intensity are not shown in the pupil as

inhomogeneous pupil illumination. Furthermore, the system pupil can be filled more uniformly with secondary light sources.

As a third method of coupling several light sources together, the segment method shall be described.

The segment method works similar to the addition method. The coupled illumination systems are uniformly distributed about a common system axis. Each system has a corresponding segment to fill the diaphragm plane. Instead of filling this segment with a circle as in the addition method, one can uniformly fill up the segment by orienting the field raster elements on the field raster element plate. Figure 11 shows the illumination of one of four segments 200 of the system pupil 202, when four sources are coupled together. In segment 200 secondary light sources 6 corresponding to the number of illuminated field raster elements are formed.

In order for the individual light bundles to be correctly superimposed in the reticle plane, pupil raster elements must be arranged at the location of the secondary light sources, which deflect the light bundles so that the images of the field raster elements are superimposed in the reticle plane. Depending on the size of the source, the pupil raster elements have planar surfaces for point like sources or concave surfaces for extended sources. Accordingly, field and pupil raster elements are tilted individually and without symmetry.

The advantage of the segment method is the optimal filling of the diaphragm plane with secondary light sources 6 by a pairwise tilting of field and pupil raster elements.

Although no optical components have been depicted in the preceding examples of embodiments of the illumination systems after the lenses or mirrors with raster

elements, it is obvious to the person skilled in the art that field lenses or field mirrors must be provided after the lenses or mirrors with raster elements in order to shape the annular field in the reticle plane and to image the diaphragm plane into the exit pupil of the illumination system, for example. This is shown in Figure 12. The illumination system of the second embodiment, shown in Figure 5 was adapted by introducing a field lens 300 between the pupil raster element plates 56.1 and 56.2. The field lens 300 represents an optical unit, which can also comprise two or more mirrors. The field lens 300 images the plurality of secondary light sources formed on the pupil raster element plates 56.1 and 56.2 into the exit pupil 310. In this regard, concerning the basic layout of EUV illumination systems, refer to the applicant's pending applications EP 99 1 06348.8, submitted on March 2,1999, entitled "Illumination system, especially for EUV-lithography", US Serial No. 09/305,017, submitted on May 4, 1999 entitled "Illumination system particularly for EUV-lithography", and PCT/EP 99/02999, submitted on May 4, 1999, entitled "Illumination system, especially for EUV-lithography", whose disclosure contents are incorporated in their entirety in the present application.

An EUV-projection exposure system is shown in Figure 13. The illumination system is already shown in Figure 12. The reticle 58 is imaged by the projection objective lens 320 onto the wafer 330. The EUV-projection exposure system can be realized as a stepper or scanning system.

Patent claims

1. Illumination system for wavelengths ≤ 193 nm, especially for EUV-lithography
with

1.1 a plurality of light sources

1.2 a mirror device for generating secondary light sources comprising several mirrors, said mirrors are comprising raster elements, whereby the illumination system is characterized in that

1.3 the plurality of light sources are coupled together in order to illuminate the exit pupil of the illumination system up to a predetermined degree of filling.

2. Illumination system according to claim 1, further characterized in that the mirrors of the mirror device for generating secondary light sources comprise raster elements for shaping the field.

3. Illumination system according to claim 2, further characterized in that several mirrors with raster elements are fashioned as field raster element plates.

4. Illumination system according to one of claims 1 to 3, further characterized in that
the raster elements are arranged on the field raster element plate and oriented so that the images of the raster elements superimpose in the plane of the object or reticle.

5. Illumination system according to one of claims 3 to 4, further characterized in that
the number of raster elements on each field raster element plate is equal.

6. Illumination system according to one of claims 3 to 5, further characterized in that
the field raster element plates are arranged on a pyramid.

7. Illumination system according to claim 6, further characterized in that the number of sides of the pyramid corresponds to the number of coupled light sources.

8. Illumination system according to claim 7, further characterized in that the coupling element is a pyramid, which serves as a carrier for the field raster element plates.

9. Illumination system according to one of Claims 6 to 8, further characterized in that
the sides of the pyramid are oriented so that the images of the raster elements of the field raster element plates are superimposed in the reticle plane.

10. Illumination system according to one of Claims 1 to 9, further characterized in that the illumination system comprises an additional mirror device, having at least one mirror with raster elements.

11. Illumination system according to claim 10, further characterized in that the additional mirror device has several mirrors with raster elements.

12. Illumination system according to one of Claims 10 to 11, further characterized in that the additional mirror device is situated at the location of the secondary light sources.

13. Illumination system according to one of Claims 10 to 12, further characterized in that the raster elements are pupil raster elements.

14. Illumination system according to claim 13, further characterized in that the pupil raster elements are arranged on a pupil raster element plate.

15. Illumination system according to claim 14, further characterized in that the pupil raster element plates are arranged on a pyramid.

16. Illumination system according to claim 15, further characterized in that the number of sides of the pyramid corresponds to the number of coupled light sources.

17. Illumination system according to claim 16, further characterized in that the coupling element is a pyramid which serves as carrier for the pupil raster element plate.

18. Illumination system according to claim 17, further characterized in that the sides of the pyramids are oriented so that the images of the raster elements of the field raster elements plate are superimposed in the reticle plane.

19. Illumination system according to claim 10, further characterized in that the additional mirror device has precisely one mirror with raster elements.

20. Illumination system according to claim 19, further characterized in that the additional mirror device is situated at the location of the secondary light sources.

21. Illumination system according to one of Claims 19 to 20, further characterized in that the raster elements are pupil raster element and a pupil raster element is situated at the location of each secondary light source.

22. Illumination system according to claim 21, further characterized in that the individual pupil raster elements are arranged on a pyramid, with only one secondary light source on each flank of the pyramid.

23. Illumination system according to claim 22, further characterized in that the number of sides of the pyramid corresponds to the number of light sources.

24. Illumination system according to one of Claims 21 to 23, further characterized in that the pupil raster elements on the pyramid flanks have a collecting mirror surface.

25. Illumination system according to one of Claims 21 to 23, further characterized in that the pyramid surfaces are planar.

26. Illumination system according to claim 25, further characterized in that the sides of the pyramid are oriented so that the images of the raster elements of the field raster element plates are superimposed in the reticle plane.

27. Illumination system according to claim 3, further characterized in that the field raster elements are distributed and tilted on the field raster element

plate such that a segment in the diaphragm plane of the illumination system is uniformly filled with secondary light sources.

28. Illumination system according to claim 27, further characterized in that an additional mirror device comprising mirrors with raster elements is situated at the location of the secondary light sources.

29. Illumination system according to claim 28, further characterized in that the raster elements of the additional mirror device are pupil raster elements.

30. Illumination system according to claim 29, further characterized in that the pupil raster elements are planar.

31. Illumination system according to claim 29, further characterized in that the pupil raster elements comprise a surface which provides a collecting effect.

32. Illumination system according to one of Claims 27 to 31, further characterized in that the pupil raster elements are distributed and tilted such that the images of the field raster elements are superimposed in the reticle plane.

33. Illumination system according to one of Claims 1 to 32, further characterized in that optical elements are situated in the optical light path after the mirror device or the several mirror devices comprising mirrors or lenses with raster elements.

34. Illumination system according to claim 33, further characterized in that the optical elements comprise field lenses or field mirrors to shape the field.

35. EUV-projection exposure system with an illumination system according to one of claims 1 to 34 further comprising
a mask
a projection objective lens
a light-sensitive object on a carrier system.

36. EUV-projection exposure system according to claim 35, designed as a scanning system.

37. Method for production of microelectronic components with a projection exposure system according to one of claims 33 to 34.

ILLUMINATION SYSTEM WITH A PLURALITY OF LIGHT SOURCES

Abstract

The invention concerns an illumination system for wavelengths ≤ 193 nm, especially for EUV-lithography with

a plurality of light sources

a mirror device for creating secondary light sources comprising several mirrors, said mirrors are comprising raster elements.

The invention is characterized in that the plurality of light sources are coupled together in order to illuminate the exit pupil of the illumination system up to a predetermined degree of filling.

Fig.1

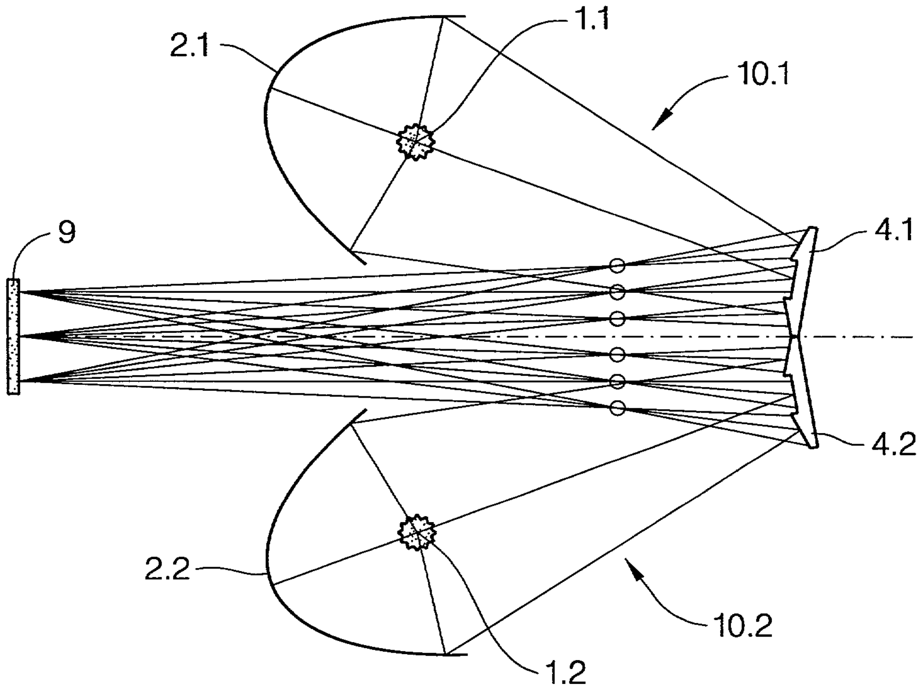


Fig.2

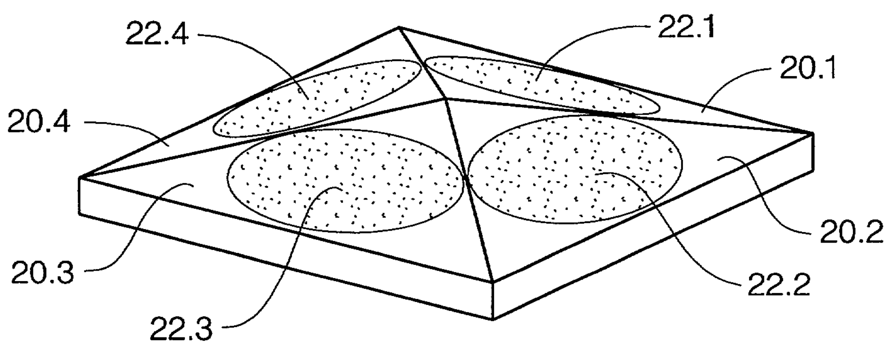


Fig.3

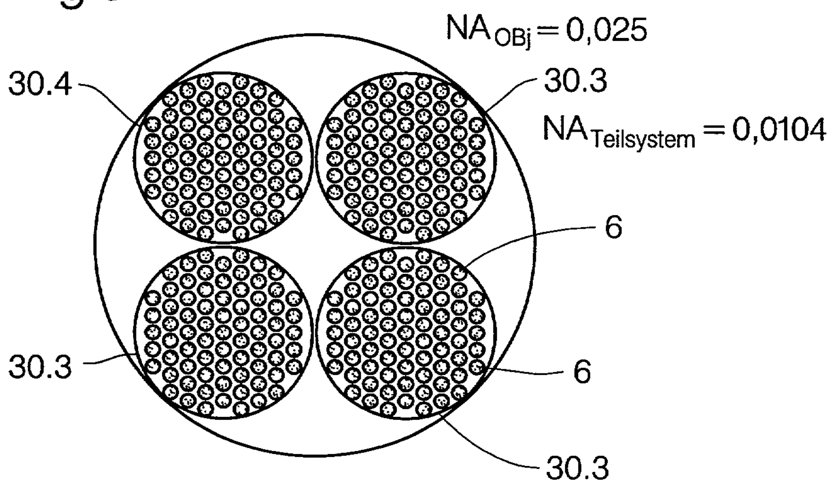


Fig.4A

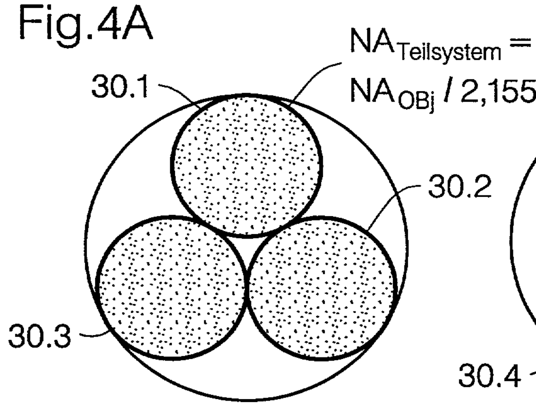


Fig.4B

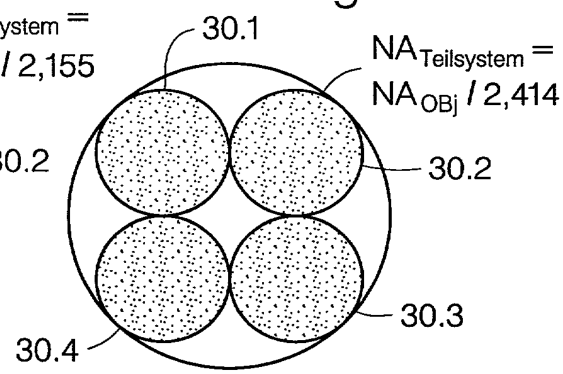


Fig.4C

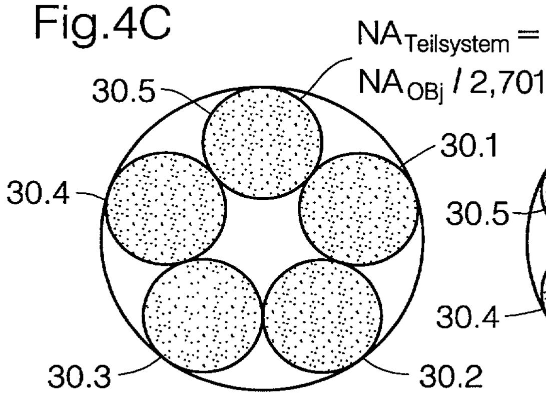
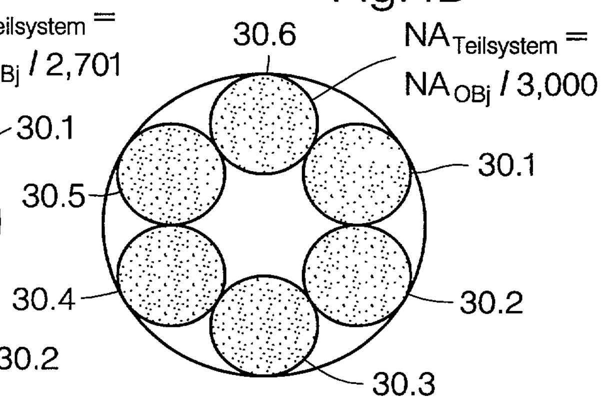


Fig.4D



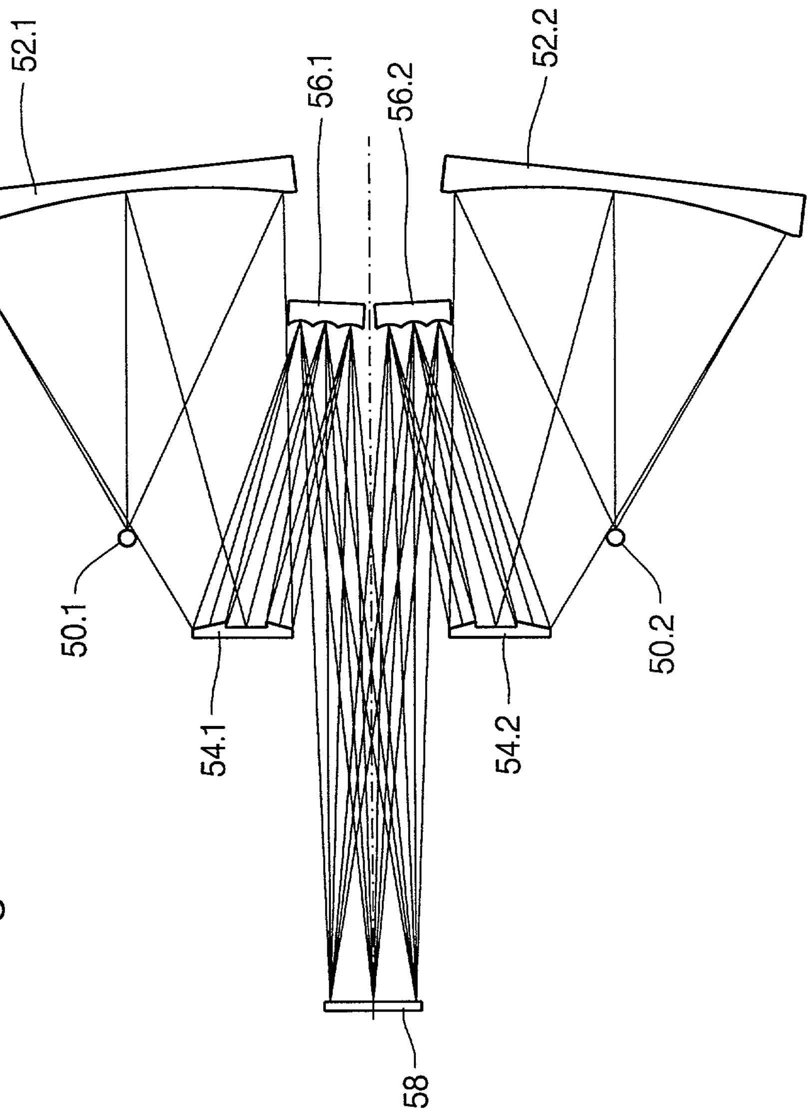


Fig.5

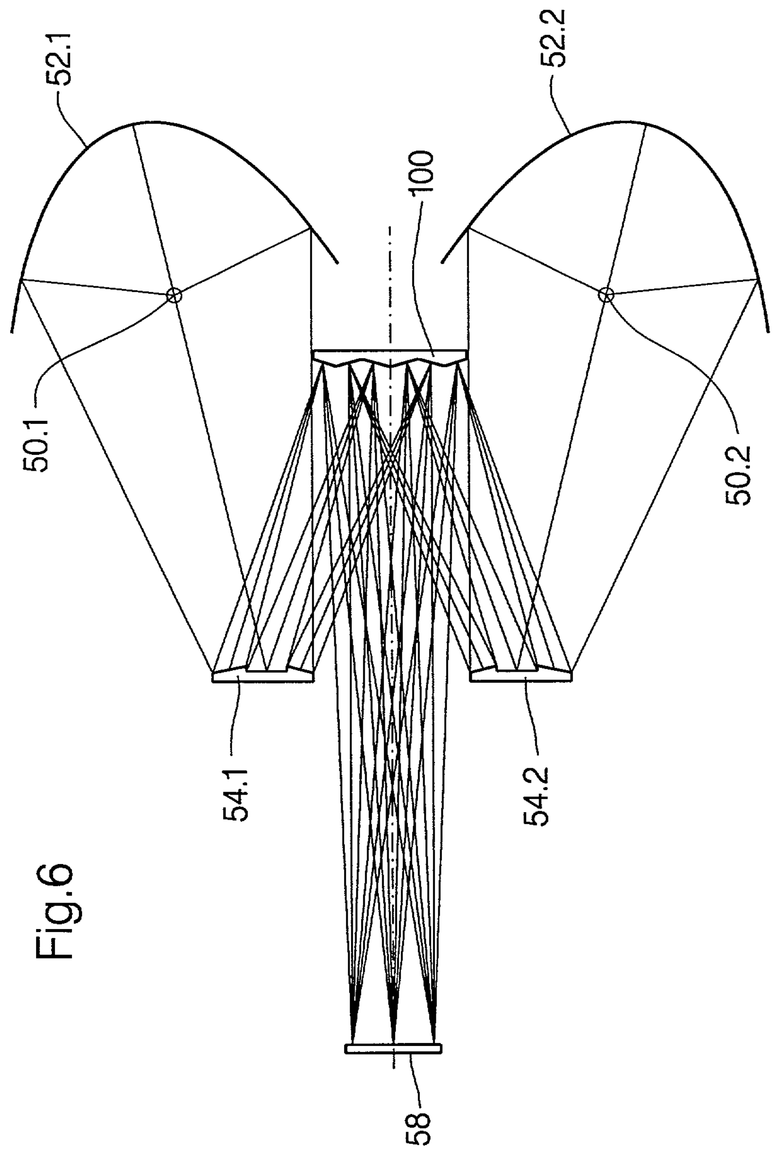


Fig.6

Fig.7

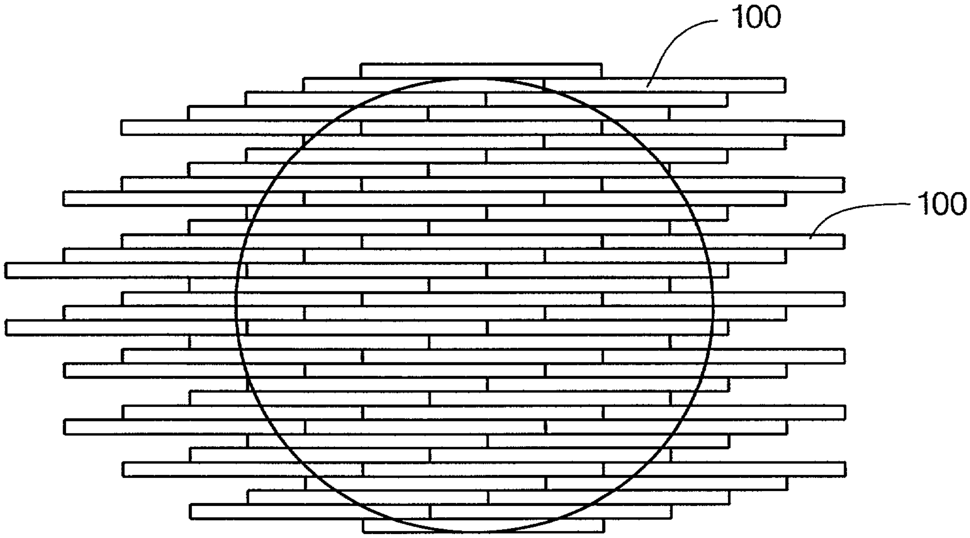


Fig.8

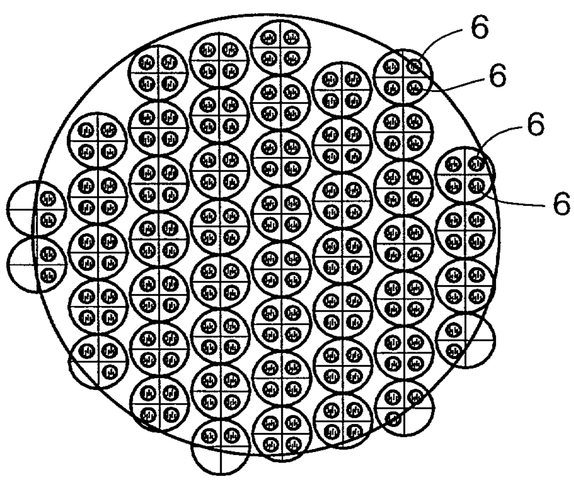


Fig.9

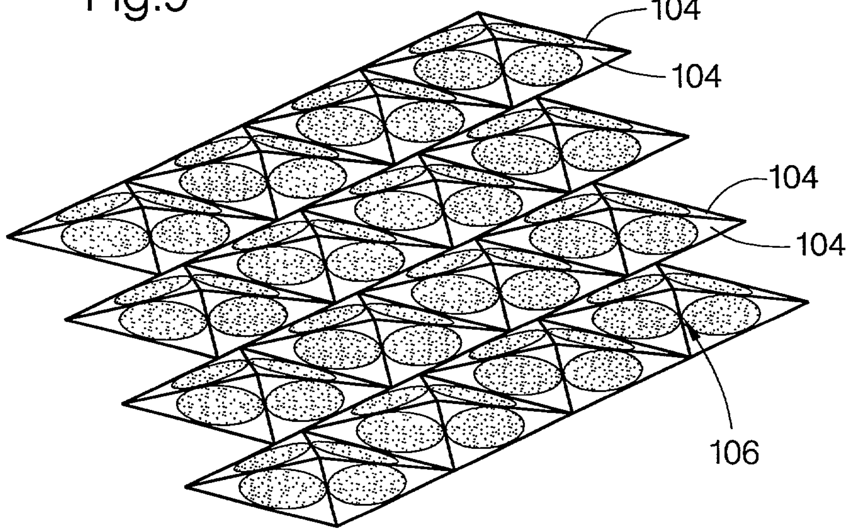
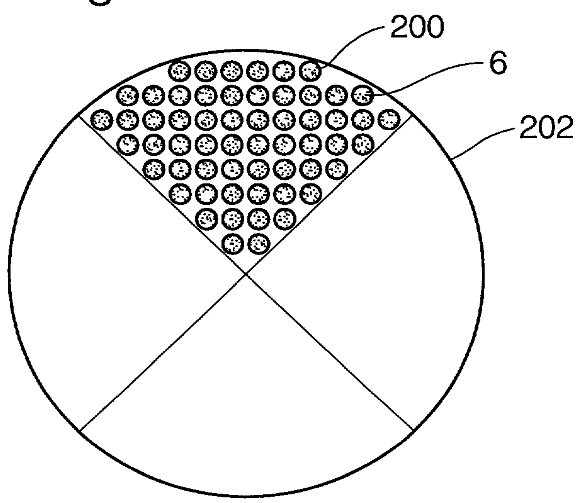


Fig.11



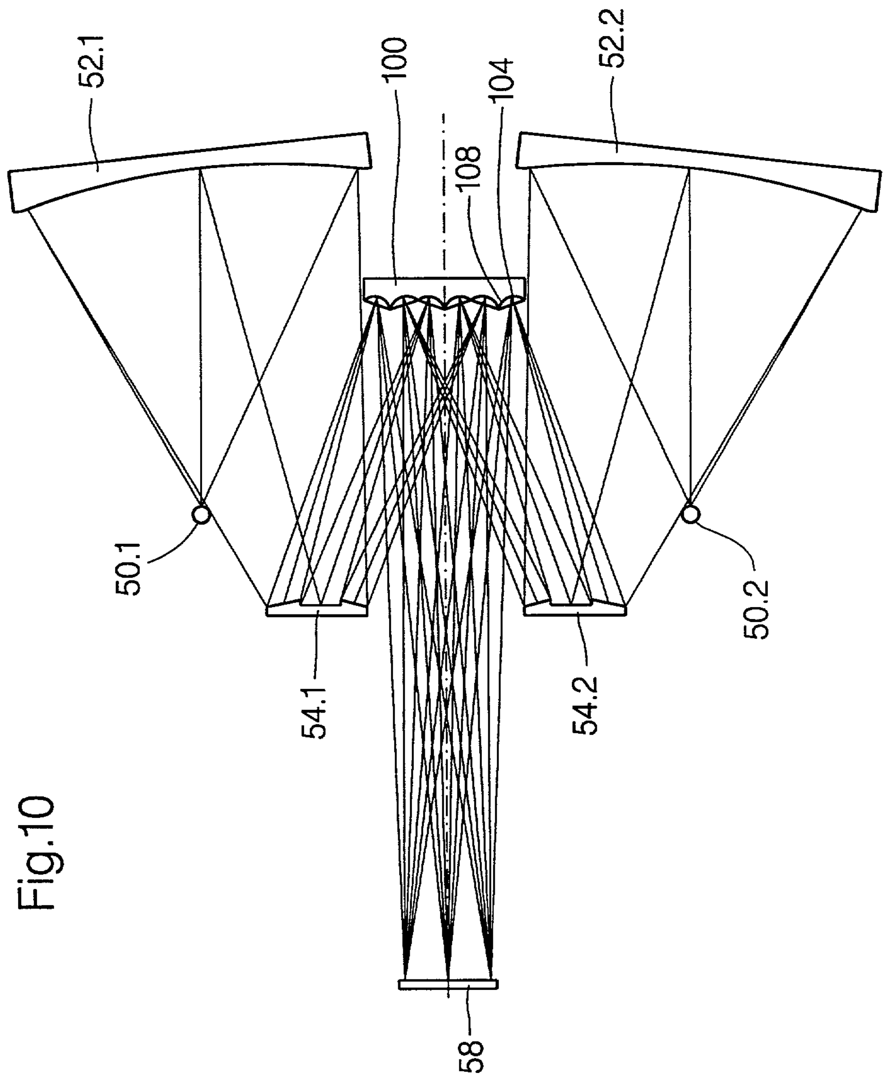


Fig.10

Fig. 12

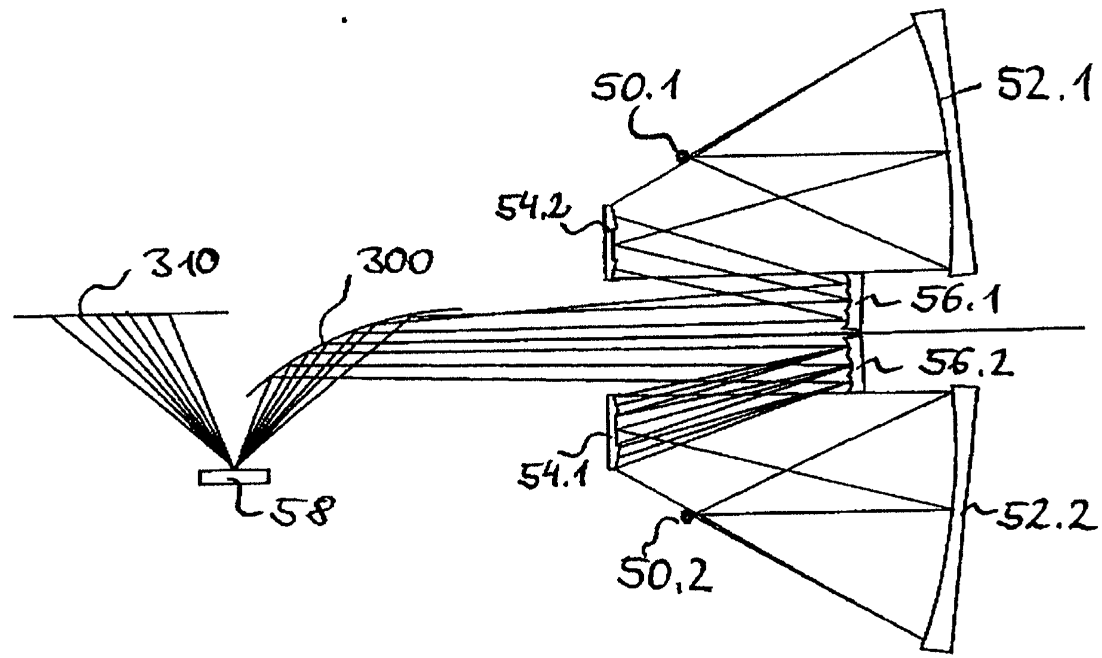


Fig. 13